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A new clinical classification and treatment strategies for temporomandibular joint ankylosis

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Abstract. Temporomandibular joint ankylosis (TMJA) is a complicated condition that affects not only the condyle, but also the maxillofacial complex. Thus, it is often challenging to find a standardized treatment strategy for TMJA. This study was performed to analyse our experience with 95 TMJA patients over a 4-year period and develop a new classification system ('CDA'). The CDA classification system divides TMJA patients into eight different groups according to the preservability of the condyle (C), severity of the dentofacial bone deformity (D), and skeletal age (A). The 95 patients (129 ankylosed joints) were treated using different strategies based on this CDA classification. Treatment options included preserving or reconstructing the condylar head, surgical correction of jaw deformities, and close follow-up of mandibular growth. After treatment, all 129 ankylosed joints were completely released and the average maximum inter-incisal opening (MIO) increased from 3.6 ± 3.2 mm to 32.8 ± 5.4 mm, with no recurrence of ankylosis found during follow-up. In conclusion, this new CDA classification can effectively guide treatment strategies for TMJA patients. Using particular strategies for patients based on specific CDA classifications could provide optimal management to the benefit of TMJA patients.

Key words: temporomandibular joint ankylosis; condyle-preserving arthroplasty; oral–maxillofacial deformity; classification.

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Temporomandibular joint ankylosis (TMJA) is characterized by bone or fibrous fusion within the joint, often leading to hypomobility[1]. TMJA patients can experience secondary maxillofacial deformity when the ankylosis affects mandibular development during the patient's growth period. Obstructive sleep apnoea/hypopnoea syndrome (OSAHS) may also occur[2].

Condylar trauma is considered to be the main cause of TMJA[3]. The incidence of

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TMJA in developing countries remains higher than in developed countries, possibly due to inadequate management of condylar trauma[4]. In a previous study, Sawhney proposed a four-stage classification for TMJA based on the pathological anatomy of the condyle, and this classification is widely accepted[5]. Other classifications of TMJA have since been put forward, which are based on various anatomical features of the ankylosed condyle[6,7]. However, differences in the onset of TMJA lead to variations in condylar dysfunction and maxillofacial deformity, limiting the utility of these single-factor classifications for guidance in medical management and subsequent surgical procedures for TMJA. A surgical plan for the treatment of TMJA requires full consideration of multiple factors, including the condyle pathology, the stage of the patient's skeletal development, and the severity of the oral–maxillofacial deformities. Thus it is challenging for surgeons without sufficient experience to achieve satisfactory therapeutic results.

The aim of this study was to propose a new classification – the 'CDA' classification – that utilizes not only the anatomical features of the condyle (C), but also takes into account dentofacial deformities (D) and the stage of skeletal development 'age' (A). This classification is based on our experience with 95 cases of TMJA over a 4-year period. We believe that this classification, which uses more detailed descriptions for the different types of TMJA, may provide a clearer guide for surgeons to follow in the surgical management of TMJA.

Materials and methods

Patients

Data from patients who underwent surgery for TMJA in the Orthognathic and TMJ Surgical Department of West China Hospital of Stomatology, Sichuan University, from January 2014 to December 2017 were analysed retrospectively. The complete medical records of all 95 patients were used, which included a thorough radiographic evaluation comprising head spiral computed tomography (CT) and lateral cephalometric radiographs taken before the operation, 1 week postoperatively, and at 6–14 months after the final surgical treatment.

Clinical classification of TMJA

The study sample of 95 patients, with a total of 129 ankylosed joints, was classified into eight groups using the proposed CDA classification system according to the condition of the joint, severity of the dentofacial bone deformity, and skeletal age.

'C' describes whether the condylar head structure could be preserved (Fig. 1): C_0, lateral bony ankylosis of both joints with the medially displaced condyle heads preserved; C_1, ankylosis of the entire joint presenting with bony fusion and no recognizable condyle or fossa on one or both sides.

'D' describes whether the patient has any secondary dentofacial deformity (Fig. 2): D_0, the patient has no significant dentofacial deformities; D_1, the patient has dentofacial deformities that affect occlusion and the appearance of the facial profile.

'A' describes the skeletal age of the patient: Ac, young patient with active dentofacial growth (skeleton immature); Aa, adult patient with a fully developed dentofacial structure (skeleton mature).

Strategies for TMJA by CDA classification

The 95 TMJA patients were divided into eight groups according to the new classification system. Different treatment strategies were used for each group. Patient numbers for each classification are listed in Table 1. Strategies for condylar preservation, the management of deformity/malocclusion, and skeletal growth follow-up for each classification are listed in Table 2. Note, a bilateral TMJA patient is classified as C_0 if both sides have medially displaced condyle heads preserved. Otherwise the patient is classified as C_1 and treated accordingly. Details of the different strategies for each classification are described below.

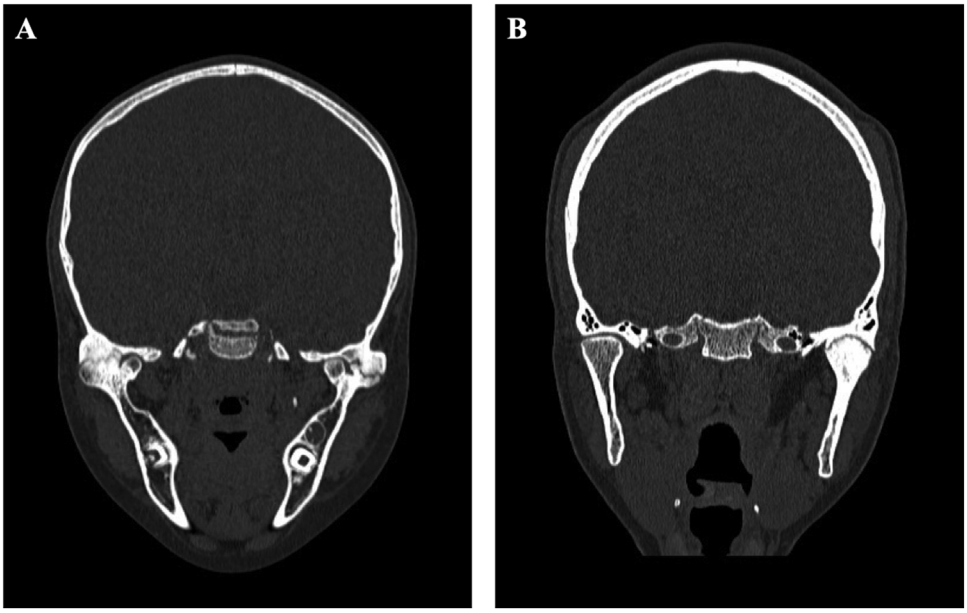

Fig. 1. The 'C' classification. (A) C_0: coronal section of a spiral CT showing bilateral lateral bony ankylosis with medially displaced condyle heads preserved. (B) C_1: coronal section of a spiral CT showing left ankylosis with bony fusion without a recognizable condyle and fossa.

Fig. 2. The 'D' classification. (A) D_0: spiral CT showing no significant dentofacial deformity. (B) D_1: spiral CT showing dentofacial deformities that affect occlusion and the facial profile symmetry.

Table 1. Number of patients by CDA classification.

Classification	Number of patients
C_0D_0Ac	9
C_1D_0Ac	2
C_0D_1Ac	11
C_1D_1Ac	11
C_0D_0Aa	9
C_1D_0Aa	8
C_0D_1Aa	10
C_1D_1Aa	34

C_0D_0Ac

The overall treatment goal for patients classified as C_0D_0Ac is to release the joint ankylosis while preserving the structure and function of the remaining condyle. Specifically, for C_0, the lateral bony ankylosis is released by condyle-preserving arthroplasty[8]. This method maintains the integrity and growth potential of the joint and has been shown to have a positive effect in promoting condylar function and facial patterns[9–11]. The residual condyle is retained in both child and adult patients. Our experience and data from the above references indicate that there are several advantages to leaving the residual condyles instead of resecting them: (1) in children, the growth site is preserved. The developmental potential of the residual condyle often avoids or reduces the occurrence of severe mandibular deformity during the patient's growth. (2) The residual disc on the surface of the condyle helps to prevent recurrence of ankylosis. (3) The existing ramus height can be maintained. (4) Reconstruction of the joint with autogenous or alloplastic material can be avoided, which represents a financial benefit for the patient. In D_0, there are no significant dentofacial deformities, but the patient often has mild malocclusion. Postoperative orthodontic treatment is suggested to achieve a favourable occlusion. Patients in the Ac group are in an active dentofacial growth period. Thus close follow-up is necessary in order to monitor mandibular growth on the side affected by TMJA. A representative case for this group is shown in Fig. 3.

C_1D_0Ac

The treatment plan for patients classified as C_1D_0Ac is to completely release the ankylosis by excision of the ankylotic block and to reconstruct the joint. For C_1, if the ankylosing mass is small enough such that its resection will not affect the ramus height, a gap arthroplasty can be performed with or without interpositional material[4]. However, in most cases, arthroplasty shortens the ramus and thus may aggravate malocclusion in the patient. In these cases, reconstruction of the joint is appropriate. Several surgical approaches for joint reconstruction have been described previously[4]. Choices for reconstruction of the condyle–ramus unit include a costochondral bone graft[12], coronoid process graft[13,14], residual ankylotic mass autograft[15], distraction osteogenesis (DO)[16,17], and total alloplastic replacement[18–20]. Each method has its own features and benefits, and in many cases there may be alternative reconstruction strategies suitable for an individual patient. Patients in the Ac group are at the stage of active dentofacial growth, so surgeons need to consider the growth potential of the graft. This is necessary to match ongoing skull development with the choice of condylar reconstructive method. We recommend that total alloplastic replacement is not performed on patients in this classification for that reason. For D_0, treatment is the same as reported in section 'C_0D_0Ac' above. For these Ac patients, close follow-up is necessary after condyle reconstruction in order to monitor the reconstructed TMJ growth in relation to ongoing skeletal development.

C_0D_1Ac

For patients classified as C_0D_1Ac, the principle approach is to release the joint ankylosis, to preserve the remaining condyle, and to correct the dentofacial deformities. Treatment of the C_0 condyle is as reported in section 'C_0D_0Ac' above. For D_1, DO is the preferred approach to correct the deformities, by elongating the underdeveloped mandibular body and ramus. Orthognathic surgery should not be performed on young patients with unstable occlusions. Second-stage orthognathic surgery can be performed when the dentofacial system is mature in order to correct any residual and emerging deformities. Again, for Ac patients, close

Table 2. Treatment strategies for the different CDA classifications.

Classification	Condyle	Deformity and malocclusion	Dentofacial skeletal growth
C_0D_0Ac	1 Release ankylosis 2 Preserve residual condyle	1 Orthodontic treatment after releasing ankylosis 2 Second-stage orthognathic surgeries when dentofacial system is mature as appropriate	1 Close follow-up when dentofacial system is immature 2 When dentofacial system is mature, correct emerging deformities with orthognathic surgery or DO
C_1D_0Ac	1 Release ankyloses 2 Reconstruct the condyle	1 Orthodontic treatment after releasing ankylosis 2 Second-stage orthognathic surgeries when dentofacial system is mature as appropriate	1 Close follow-up when dentofacial system is immature 2 When dentofacial system is mature, correct emerging deformities with orthognathic surgery or DO
C_0D_1Ac	1 Release ankylosis 2 Preserve residual condyle	1 Correct maxilla/mandible bone deformity by DO 2 Orthodontic treatment after releasing ankylosis	1 Close follow-up when dentofacial system is immature 2 When dentofacial system is mature, correct emerging/remaining deformities with orthognathic surgery or DO
C_1D_1Ac	1 Release ankylosis 2 Reconstruct the condyle	1 Correct maxilla/mandible bone deformity by DO 2 Orthodontic treatment after releasing ankylosis	1 Close follow-up when dentofacial system is immature 2 When dentofacial system is mature, correct emerging/remaining deformities with orthognathic surgery or DO
C_0D_0Aa	1 Release ankylosis 2 Preserve residual condyle	1 Orthodontic treatment after releasing ankylosis	1 Follow up 3, 6, 12 months after surgery, then regular follow-up annually
C_1D_0Aa	1 Release ankylosis 2 Reconstruct the condyle	1 Orthodontic treatment after releasing ankylosis	1 Follow up 3, 6, 12 months after surgery, then regular follow-up annually
C_0D_1Aa	1 Release ankylosis 2 Preserve residual condyle	1 Correct maxilla/mandible bone deformity by orthognathic surgery or DO 2 Orthodontic treatment after releasing ankylosis	1 Follow up 3, 6, 12 months after surgery, then regular follow-up annually
C_1D_1Aa	1 Release ankylosis 2 Reconstruct the condyle	1 Correct maxilla/mandible bone deformity by orthognathic surgery or DO 2 Orthodontic treatment after releasing ankylosis	1 Follow up 3, 6, 12 months after surgery, then regular follow up annually

DO, distraction osteogenesis.

follow-up is required (see section 'C_0D_0Ac' above).

C_1D_1Ac

The treatment strategies for patients classified as C_1D_1Ac include completely releasing the ankylosis, reconstructing the joint, correcting the dentofacial deformities, and close follow-up until the dentofacial system matures. The treatment of C_1 is as reported in section 'C_1D_0Ac' above, and the treatment of D_1 is as reported in section 'C_0D_1Ac' above. DO is used to both reconstruct the joint and to ameliorate the mandibular hypoplasia. Second-stage orthognathic surgery may be performed at skeletal maturity, depending on the patient's emerging orofacial deformities. For Ac patients, close follow-up is required (see section 'C_1D_0Ac' above). A representative case from this group is shown in Fig. 4.

C_0D_0Aa

When the patient is classified as C_0D_0Aa, the treatment goal is simply to correct the joint ankylosis by condyle-preserving arthroplasty. For the treatment of C_0, see section 'C_0D_0Ac' above, and for D_0, see section 'C_0D_0Ac' above. Since dentofacial skeletal growth of the Aa patient has been completed, only regular follow-up is suggested, in order to prevent re-ankylosis.

C_1D_0Aa

For patients classified as C_1D_0Aa, the treatment goal is to completely release the ankylosis and surgically reconstruct the joint. The treatment of C_1 is as reported in section 'C_1D_0Ac' above. A patient in this group has completed mandible development, making total alloplastic replacement an alternative for joint reconstruction. This method should achieve proper TMJ function and occlusion. For D_0, see 'C_0D_0Ac' above. Follow-up of the Aa patient is as reported in section 'C_0D_0Aa' above.

C_0D_1Aa

The plan in the C_0D_1Aa patient is to release the ankylosis, preserve the residual condyle, and correct secondary dentofacial deformities. The C_0 condyle is treated as in 'C_0D_0Ac' above. With regard to the D_1 deformity, the patients typically have differing extents of malocclusion due to the disruption of condylar growth and a long-term limitation of mouth opening ability. Therefore, a series of orthognathic surgical approaches is necessary after arthroplasty to ameliorate the secondary deformity caused by TMJA: (1) a Le Fort I osteotomy is required to bring the shortened hemimaxilla (in unilateral cases) or the shortened posterior maxilla (in bilateral cases) down. The resulting gap is filled with a bone graft. (2) The mandibular deformities typically include dysplasia of the mandible body and the ramus. A sagittal split ramus osteotomy (SSRO) is usually performed to advance the retruded mandible body. An intraoral vertical ramus osteotomy (IVRO) can restore the ramus length and the condyle. Alternatively, an inverted 'L' osteotomy of the ramus with bone graft and DO can achieve both of these treatment goals. The choice of strategy is based on the severity of the bone deficiency. (3) Finally, an advancement or levelling genioplasty is performed to correct the genial deformity. Follow-up

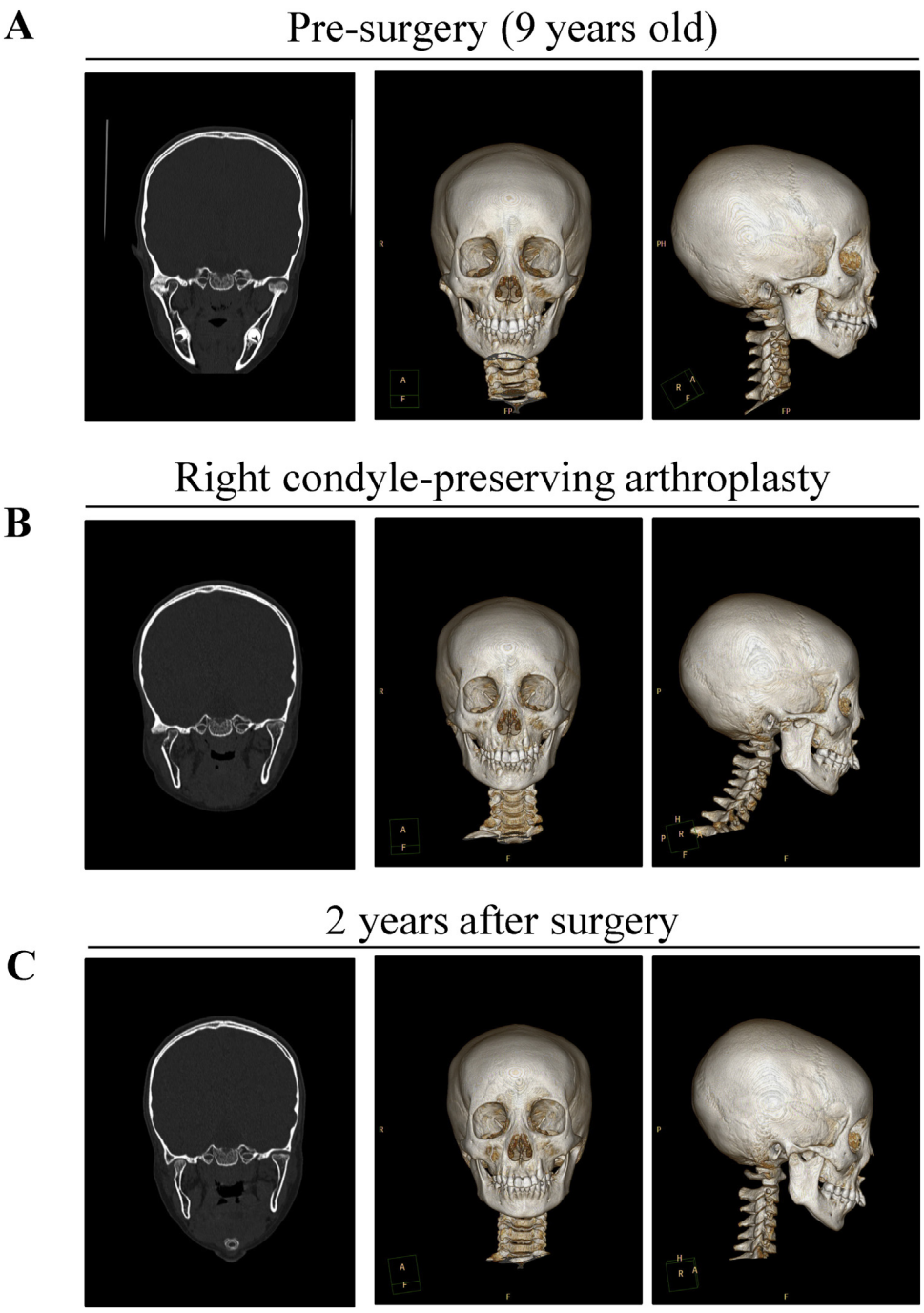

Fig. 3. A representative case of C_0D_0Ac. (A) A 9-year-old female patient presented with right TMJA and no jaw deformity. (B) The right lateral bony ankylosis was released by condyle-preserving arthroplasty. (C) The 2-year follow-up observation showed no significant deformity, indicating the capacity for the preserved right condyle to develop in concert with the left condyle.

of the Aa patient is as reported in section 'C_0D_0Aa' above. A representative case from this group is shown in Fig. 5.

C_1D_1Aa

For patients classified as C_1D_1Aa, the treatment goal is to completely release the ankylosis, to reconstruct the joint using an autograft, DO, or total alloplastic replacement, and to ameliorate the secondary deformity resulting from TMJA using orthognathic surgery approaches. For the treatment of C_1, see 'C_1D_0Aa' above, and for the treatment of D_1, see 'C_0D_1Aa' above. DO can be used to both reconstruct the joint and partially correct the mandibular deformities. If DO is chosen, a second-stage orthognathic surgery could be performed later to remove the distractor. Follow-up of the Aa patient is as reported in section 'C_0D_0Aa' above. A representative case from this group is shown in Fig. 6.

Outcome evaluation

Beginning 1 week after arthroplasty surgery, the patients were required to perform mouth opening exercises over a period of

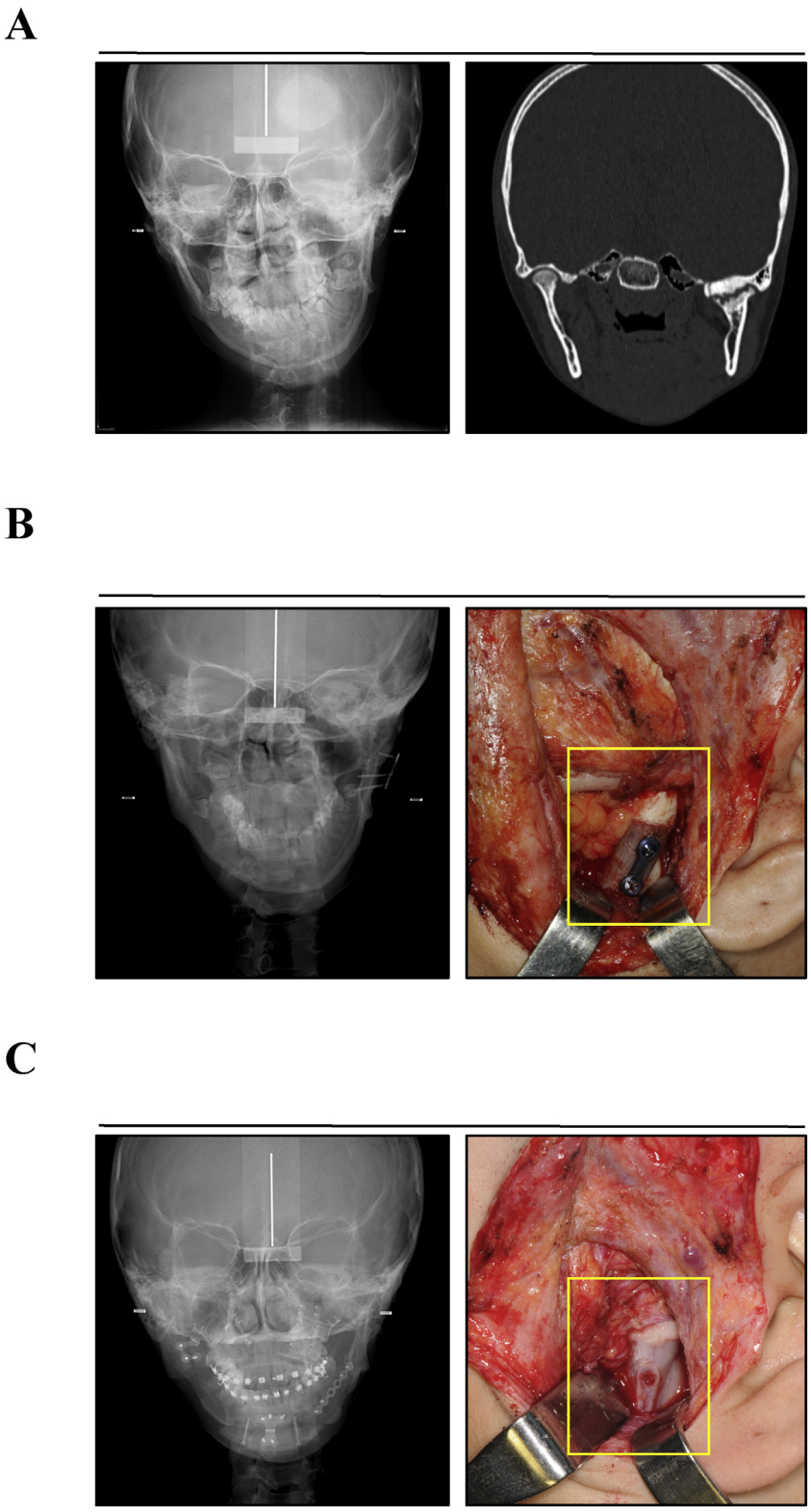

Fig. 4. A representative case of C_1D_1Ac. (A) A 16-year-old female patient presented with left TMJA, combined with secondary mandibular retrusion and mild maxillofacial asymmetry. A two-stage treatment protocol was used for this patient. (B) In the first stage, a right arthroplasty was performed to release the ankylosis and a costochondral bone graft was used to reconstruct the resected condyle. (C) When the patient was 18 years old, second-stage orthognathic surgeries were performed to correct the patient's maxillofacial deformity. These included Le Fort I osteotomy, bilateral mandibular sagittal split ramus osteotomy, and genioplasty. The internal fixed plates of the costochondral bone graft were removed and it was found that the graft had resulted in a normal condyle head. The ankylosis and deformity were both well corrected using this two-stage treatment approach.

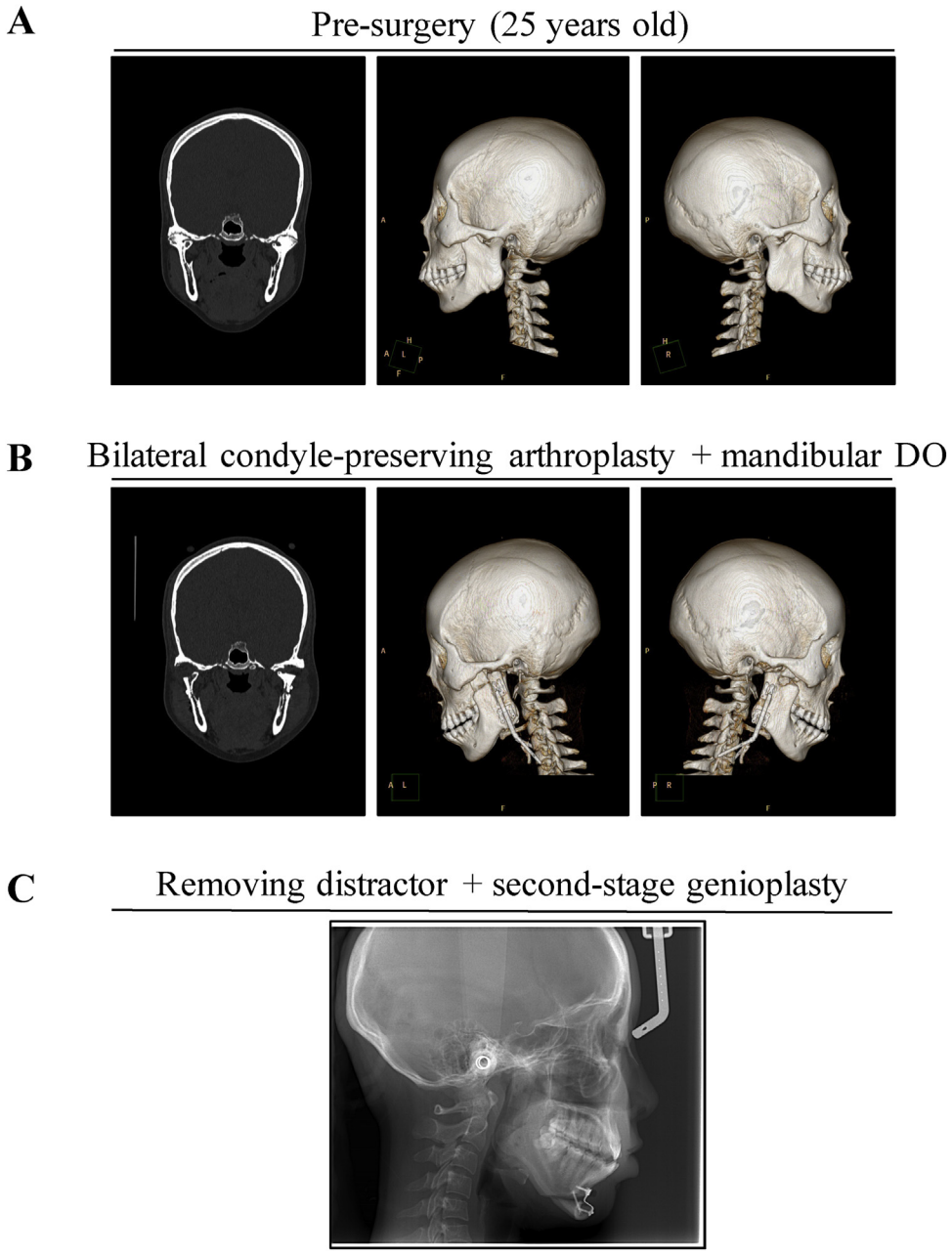

Fig. 5. A representative case of C_0D_1Aa. (A) A 25-year-old female patient exhibited bilateral TMJA with mandibular retrusion. (B) The treatment strategy consisted of bilateral condyle-preserving arthroplasties to release the ankylosis and bilateral mandibular DO to extend the stunted ramus and correct the mandibular retrusion. (C) The distractor was later removed and a genioplasty was performed to further improve the patient's profile.

3 months. Patient follow-up was conducted for 6–14 months, depending on the CDA classification, in order to review changes in maximum inter-incisal opening (MIO) and the mandibular length on the ankylosed side. The release and recurrence of the ankylosis were identified by spiral CT to determine whether there was union between the condyle and the fossa and by MIO changes. Amelioration of dentofacial deformities was assessed by cephalometric analyses using X-ray and spiral CT in the short-term (6–14 months after the final surgical treatment). However, changes in the reconstructed condyle and remodelling effects will need to be evaluated later during long-term follow-up.

Statistical analysis

All data were expressed as the mean ± standard deviation values. To determine the statistical significance of longitudinal comparisons, the data were analysed using paired *t*-tests. The independent samples *t*-test was used for intergroup comparisons of MIO. Differences were considered statistically significant when the *P*-value was less than 0.05.

Results

This study included 34 bilateral and 61 unilateral cases, for a total of 95 TMJA patients. The age of the patients ranged

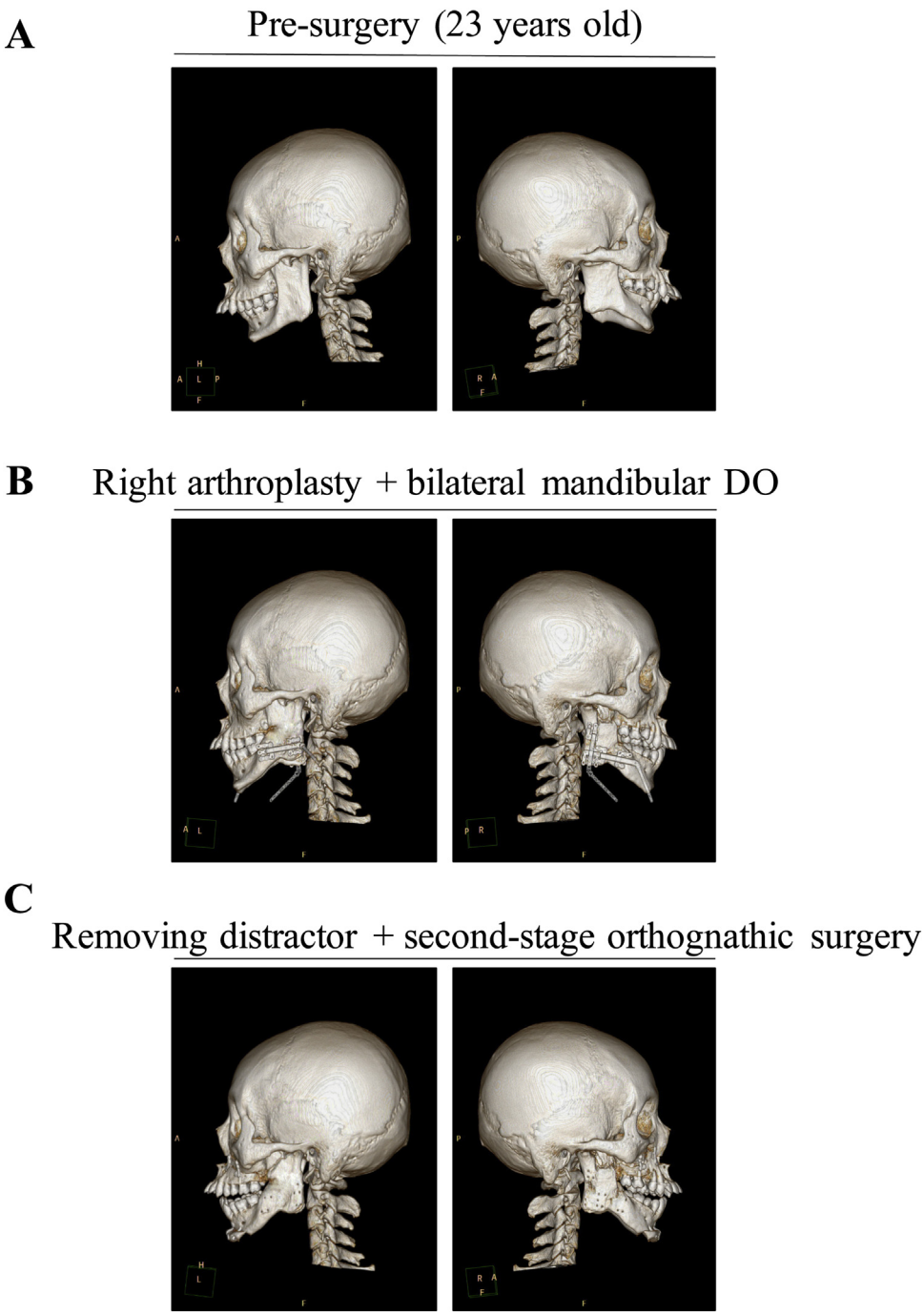

Fig. 6. A representative case of C_1D_1Aa. (A) A 23-year-old male patient was diagnosed with right TMJA with mandibular retrusion and asymmetry. (B) The first-stage treatment strategy included a right arthroplasty to release the ankylosis, right mandibular DO to reconstruct the joint, and bilateral DO to correct the mandibular retrusion. (C) The second-stage treatment strategy included Le Fort I osteotomy to correct the maxilla deviation and a genioplasty to improve the patient's profile. Significant amelioration of the facial symmetry was achieved upon treatment.

from 6 to 67 years, with an average age of 25 ± 13 years. There were 50 male patients and 45 female patients. The classification information is summarized in Table 3. Of the total joints, 34.1% were classified as C_0 (Fig. 1A) and 65.9% as C_1 (Fig. 1B) based on CT scans. With regard to the D classification, 29.5% of patients were classified as D_0 (Fig. 2A), while 70.5% of patients were classified as D_1 (Fig. 2B). There were 34 Ac patients (35.8%) and 61 Aa patients (64.2%).

In terms of the CDA classifications (Table 1), 9.5% of patients were classified as C_0D_0Ac, 2.1% as C_1D_0Ac, 11.6% as C_0D_1Ac, 11% as C_1D_1Ac, 9.5% as C_0D_0Aa, 8.4% as C_1D_0Aa, 10.5% as C_0D_1Aa, and 35.8% as C_1D_1Aa.

Patients were assigned a CDA classification, and the treatment approaches used were as described above and summarized in Table 2. All 129 instances of ankylosis were completely released after surgery. There was no recurrence of ankylosis in

Table 3. List of patients by CDA classification.

Condyle persistence (C)	Number of joints	Dentofacial deformity (D)	Number of patients	Skeletal age (A)	Number of patients
C_0	44	D_0	28	Ac	34
C_1	85	D_1	67	Aa	61
Total	129	Total	95	Total	95

any patient after 6–14 months of observation. At 6–14 months after surgery, the average MIO of the patients increased from 3.6 ± 3.2 mm to 32.8 ± 5.4 mm ($P < 0.001$). Regarding the secondary clinical outcomes, dentofacial deformities in the 67 patients classified as D_1 were significantly ameliorated, as assessed by comparison of cephalometry data between preoperative and postoperative X-ray and spiral CT during the 6–14-month short-term observation period.

Complications observed included crepitus in the reconstructed joint area in 11 of 129 joints (8.5%), transient injury of the temporal and zygomatic branches of the facial nerve in five of 95 patients (5.3%), and infection of the surgical area in two of 95 patients (2.1%).

Discussion

The treatment of TMJA is a great challenge due to the complicated clinical manifestations in patients, including varying degrees of joint destruction, distinct dentofacial deformities, and different periods of skeletal development. Traditional classifications have been simple and one-dimensional, based on the location (intra- or extra-articular), type of tissue involved (fibrous, fibro-osseous, or osseous), or extent of the fusion (complete or incomplete)[5–7,21]. In our experience of clinical TMJA management, these have not been sufficient. How should the ankylosed bone be removed for both early mobilization of the joint and preserving TMJ growth potential? Which approach is optimal for reconstructing the TMJ in different patients? When should orthognathic surgery be used to correct secondary dentofacial deformities? A comprehensive approach that answers these clinical questions has not been provided by the previous TMJA classifications. For better guidance on TMJA management, we developed this new CDA classification, which describes TMJA utilizing multiple factors.

The condylar head fibrocartilage is considered to be the primary mandibular growth site[22]. In TMJA patients, cartilage on the TMJ surface is severely damaged, thus mandibular developmental disorders and secondary dentofacial deformities may occur during their growth period. TMJA is a dynamic process and involves a series of compensational and pathological changes. Thus, single-factor classification (e.g. complete or incomplete fusion of the joint) is unable to comprehensively account for all disease features. Therefore, all three factors, 'C', 'D', and 'A', must be considered together during treatment strategy planning. Using the CDA classification, the 95 patients were divided into eight groups. Each group was described using all three factors. Customized treatment plans including surgical interventions and close follow-up were then devised for each particular TMJA patient according to the CDA classification.

It was observed that over one-third of the patients (35.8%) were classified as C_1D_1Aa. This group had the largest number of patients, and this classification signifies that TMJA has already developed to the most serious level and the latest stage. Meanwhile, the number of Aa patients was nearly two-fold the number of Ac patients ($n = 61$, 64.2% vs. $n = 34$, 35.8%). This could be due to delayed treatment interventions during the growth period in some Aa patients. These findings are consistent with the fact that the onset of most TMJA cases occurs in underdeveloped regions that lack early management of condylar fractures and where there is limited use of antibiotics[23,24]. Coincidently, 67 out of 95 patients (70.5%) were classified as D_1. Unlike D_0 patients, these patients need surgery not only to release the ankylosis but also to correct dentomaxillofacial deformities arising from ankylosis.

There is also an important non-medical factor to take into consideration when planning treatment – the financial cost to the patient. We have often encountered patients who face a large financial problem because of their poor financial status and the relatively high cost of multiple surgeries. This has inspired us to continue promoting medical health missionary efforts. We also emphasize that the early management of TMJA in underdeveloped countries may reduce treatment costs in addition to effectively decreasing the incidence of TMJA in these areas.

In conclusion, the CDA classification presented here is more comprehensive than traditional, single-factor classifications for guiding management strategies for TMJA. Treatment plans specific for patients in the different CDA classifications could help target interventions in each TMJA patient to achieve optimal treatment outcomes.

Funding

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Competing interests

None.

Ethical approval

This study was approved by the Institutional Review Board of West China Hospital of Stomatology, Sichuan University (number WCHSIRB-OT-2018-067).

Patient consent

Informed consent agreements were signed by all patients included in this study.

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